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α_S from Spectroscopy of ψ- and Υ-particles in QCD Sum Rules

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Abstract

In a specific scheme of the QCD sum rules, one gives the estimate of $\alpha_S \simeq 0.20$ from the data on the masses and leptonic constants of ψ- and Υ-particles.

The characteristic value of the quark-gluon coupling in QCD for the systems of the charmonium ($\bar{c}c$) and bottomonium ($\bar{b}b$) is generally estimated from the branching fractions of the radiative and leptonic decays of vector states $Br(Q\bar{Q} \to \gamma X) \simeq \Gamma(Q\bar{Q} \to \gamma gg)/\Gamma(Q\bar{Q} \to ggg)$, $Br(Q\bar{Q} \to l^+l^-) \simeq \Gamma(Q\bar{Q} \to l^+l^-)/\Gamma(Q\bar{Q} \to ggg)$ [1], so these ways do not depend on a modelling of the heavy quarkonium wave function. However, such estimates contain the uncertainty, related with a model for the gluon hadronization. For instance, one can think, that the gluons have a nonzero virtuality of the order of the confinement scale or higher corrections generate a nonzero effective dynamical mass of the gluon [2]. The α_S estimates from the total cross sections for the hadronic production of the c- and b-quarks also contain the uncertainties, related with an account of higher corrections in the perturbation theory of QCD (the K-factor), a choice of the quark mass values and a model-dependence of the parton distributions. Therefore, one generally supposes $\alpha_S(\psi,\ \Upsilon) \simeq 0.3 \div 0.2$. It would be useful one to obtain the characteristic α_S value for the ψ- and Υ-particles, using another way of the estimate.

To get the α_S estimate, in the present paper we use the relations, obtained in the framework of the QCD sum rules [3] for the leptonic constants and masses of the heavy quarkonia.

In the recently offered scheme of the QCD sum rules [4], in the leading approximation over the inverse heavy quark mass and with an account of the coulomb-like α_S/v-corrections, one has got the relations for the leptonic constants f_n of the heavy quarkonium nS-levels, lying below the threshold of the decay into the heavy meson pair, [4]

$$\frac{f_n^2}{M_n} = \frac{\alpha_S}{\pi}\ \frac{dM_n}{dn}\ , \tag{1}$$

and for the difference of the level masses [5]

$$M_n - M_1 = \frac{dM_n}{dn}(n=1)\ln n \ . \tag{2}$$

Since the heavy quark potential is close to the logarithmic one [6], the quarkonium level density dn/dM_n does not depend on the heavy quark flavours. Therefore, with the accuracy up to logarithmic loop-corrections, one gets, that

$$\frac{f^2}{M} = const.\ , \tag{3}$$

and

$$\frac{M_n - M_1}{\ln n} = const. \tag{4}$$

The data on the ψ- and Υ-particle spectroscopy show, that relations (3) and (4) are valid with a good accuracy ($\leq 10\%$) [4,5]. Then one can obtain the reliable estimate for the α_S value

$$\alpha_S = \pi\ \frac{f^2_{1S}}{M(1S)}\ \frac{\ln 2}{M(2S)-M(1S)}\ , \tag{5}$$

so that the quantities in the right hand side of eq.(5) are well known experimentally. From eq.(5) it follows, that

$$\alpha_S(\psi,\ \Upsilon) \simeq 0.20 \pm 0.02\ , \tag{6}$$

where the error corresponds to the accuracy of the approach as the whole.

If one uses the one-loop expression for the "running" constant $\alpha_S(\mu) = 2\pi/(11 - 2n_f/3)\ln \mu/\Lambda$, where $n_f = 3$ is the number of light quarks, Λ is the one-loop renormalization invariant, then, accepting the mean value in eq.(6) and $\mu = (m_\psi + m_\Upsilon)/2$, we get $\Lambda \simeq 0.14$ GeV and $\alpha_S(\psi) = 0.25 \pm 0.03$, $\alpha_S(\Upsilon) = 0.18 \pm 0.02$, that is in a good agreement with estimate (6).

Thus, in the framework of the QCD sum rules and on the basis of the spectroscopic data, one gets the reliable estimate of α_S for the ψ- and Υ-systems.

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